

ALLOGRAPHIC VARIATIONS AND STATISTICAL ANALYSIS OF THE RONGORONGO SCRIPT¹

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Rongorongo, the writing of Easter Island, has evoked great scientific interest since its discovery. From the numerous inscribed artifacts observed by Eyraud in 1864 (Englert 1948:315), only a few survive. The known corpus mainly consists of wooden tablets, one staff, two *reimiro*, a birdman figure with several incised signs, and a snuffbox made from a tablet. The signs of the script were carved with obsidian flakes or shark teeth (Routledge 1919:244), sometimes along preformed grooves. The lines follow each other in reverse boustrophedon fashion. Initially this technique was probably developed for writing over staves, and later adapted for tablets (Métraux 1940:405).

The nature of the script has been intensively disputed. The first glyph catalog, published in 1893, was composed by Jaussen, the Bishop of Tahiti, on the basis of tablet readings by Metoro (a native Rapanui working in Tahiti) (Heyerdahl 1965: Figures. 83-94). In the mid-20th century, the parallelism of three *rongorongo* texts was discovered by Kudryavtsev, who made a catalog of 427 signs on two tablets from the Museum for Anthropology and Ethnography (MAE), St. Petersburg (Kudryavtsev 1949:194-209). Barthel (1958) developed a catalog of 632 possible glyphs and a method of transliteration to describe all the surviving inscriptions. In this paper, we will use Barthel's notation for the tablets, lines and individual signs; glyph numbers are zero-filled to three-digit form according to the CEIPP extended Barthel System. The great number of different signs used in writing naturally suggest the conclusion of a pictographic or ideographic character to the script, correlating well with significant amount of glyphs depicting beings or objects (Figure 1); however, many composite signs defy interpretation, even with the help of the islanders (Métraux 1940:394, Fedorova 1963:86).

Analysis of the frequency of glyph duplication proves

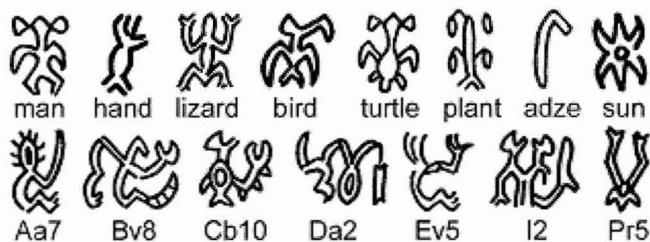


Figure 1. Examples of *rongorongo* signs depicting easily identifiable and non-identifiable objects.

that the tablets were written in a Polynesian language group (Fedorova 1963:87). At the same time, no signs of high usage frequency were found (comparable to that of articles and other auxiliary parts of speech), suggesting only key words were written (e.g. Fedorova 1983:50). Other structural peculiarities, such as suffix position of the supposed patronymic-related

sign 076 in the probable genealogy in line Gv6 (Butinov, Knorozov 1956:87), suggests that the language of *rongorongo* was archaic and significantly different from both the modern Rapanui language and that used in the 19th century (Fedorova 1963:91). Structural correspondences between the script and native pre-missionary cosmogonies were investigated by Fischer, suggesting that the inscriptions contained procreation chants (Fischer 1995:312). Fedorova proposed tentative readings of the tablets, showing the strong relation of the script to agricultural activities of the islanders (Fedorova 2001:115-352).

Scholars analyzing possible allographic variations in the Barthel catalog have made several suggestions to reduce it to 300 signs (Fedorova 1983:47), 120 signs (Pozdniakov 1996:297), and 70 signs (Macri 1996:185). The latter figure is close to 50, the number of Rapanui syllables (Fedorova 1963:87), supporting the hypothesis of a syllabic nature for the script (Pozdniakov 1996: 297, Macri 1996: 185). Pozdniakov also described mini-texts, e.g. stable glyph sequences appearing on different tablets (Pozdniakov 1996:295). Macri suggested that compound signs are composed of simplified basic glyphs (Macri 1996:186).

Some doubts still remain concerning proper identification of the textual beginnings of tablets A, D, N, R, S (Pozdniakov 1996: 298-299) and I (Guy 2004:41). It is curious that the lines of three *rongorongo* artifacts, namely Bv2, Bv3 (Englert 1948:324, photo), Er2, Er3 (Fischer 1997:436), Ev1, Ev2 (Chauvet 1945: Figs. 158, 159) and I12, I13 (Guy 2004:41) merge together, possibly meaning that the text was written in parts or separating subtexts on the same tablet. The order of glyph reading in parallel text fragments proved left-to-right reading for horizontal ligatures (juxtaposed signs), while vertical ones (stacked signs) were probably read bottom-to-top (Guy 1982:447, Pozdniakov 1996:297), following tablet writing directions (Figure 2). Symbol elements can also be rotated to form ligatures (Métraux 1940:402, Guy

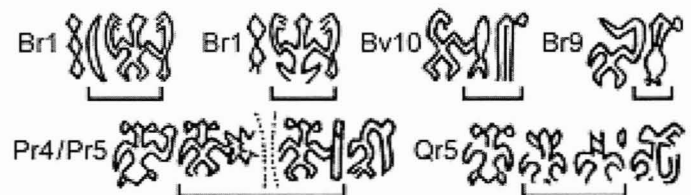


Figure 2. Examples of vertical and horizontal ligatures.

1982:447, Pozdniakov 1996: 297).

No general agreement is found on the nature of *rongorongo* script, the number of glyphs used in writing, and the possible sign variants. This paper presents a partial solution to the problem. Script fragments were traced from photos of the original tablets (Chauvet 1945, Englert 1948, Butinov

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and Knorozov 1956, Heyerdahl 1975, CEIPP 1982, Orliac 1995, Campbell 1999, Kjellgren 2001, Flenley and Bahn, 2002).

STATISTICS OF THE TRANSLATED SCRIPT

The analyzed *rongorongo* corpus in Barthel's notation included 632 different glyphs, from a total of 14,552 signs. A probability-rank $P(r)$ plot for glyphs shown in Figure 3, approximates well with the Mandelbrot law (Montemurro 2001:567)

$$P(r) = k / (r + \rho)^\varepsilon, \quad (1)$$

with normalization coefficient k and language-dependant parameters ρ and ε . Similar to the case of natural languages, the curve features two segments with different slopes (Figure 3, dashed lines), corresponding to frequently and rarely used signs. For comparison, the same figure presents a $P(r)$ plot for 1,679 words forming a lexicon of analyzed Rapanui legends (Métraux 1940, Englert 1948, Fedorova 1978) and manuscripts (Heyerdahl 1965: Figs 123-146, 161-170, Fedorova 1978; Fedorova 1988:15-45 for manuscript E). The original 43,836-word text was expanded to 45,144 words, splitting causative *haka* and reduplicated forms to account for them correctly (e.g., *hakarivariva* was considered as *haka riva riva*). The resulting corpus included 133,597 letters and 79,658 syllables, yielding an average of 2.959 letters or 1.765 syllables per word and 1.677 letters per syllable.

As it follows from Figure 3, both $P(r)$ curves show a similar character, assuming the correlation between the signs identified by Barthel and the words of Rapanui language. The entropy, calculated as (Ventzel 1962:460)

$$H = -\sum P_i \log_2 P_i, \quad (2)$$

yields very similar values for both glyphs and words (Figure 3), also suggesting that each sign may represent a separate word. If the possible phonetic elements of the script obey the same statistics as the analyzed folklore texts, one can expect that the average glyph may consist of about three elements corresponding to letters or two elements of a certain syllabic value. This assumption correlates well with the hypothesis treating compound glyphs as superpositions of simpler forms

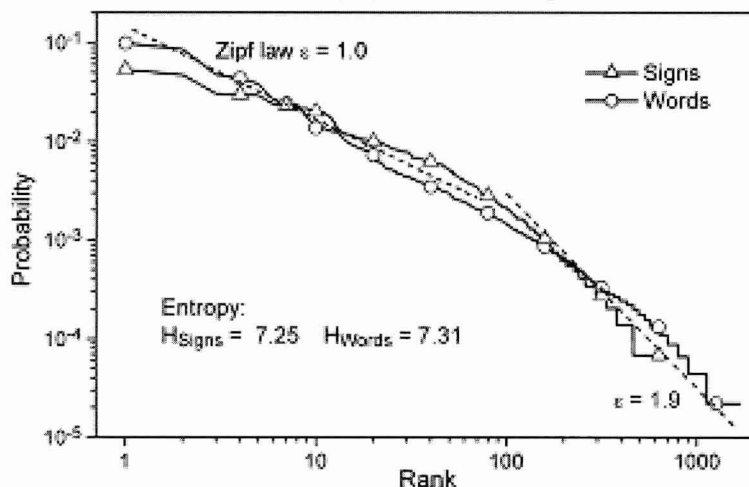


Figure 3. Probability-rank plot for *rongorongo* signs and words of Rapanui folklore texts.

(Kudryavtsev 1949:183, Guy 1982:447, Fedorova 1982:68, Macri 1996:186). It also explains the existence of signs without a clear pictographic identification (Figure 1), composed according to their phonetic value rather than depicting real-life objects. Another important consequence from the similarity of statistical characteristics observed in Figure 3 is the possibility of using Rapanui folklore for a comparative statistical analysis of *rongorongo*.

PALEOGRAPHIC ANALYSIS OF THE SCRIPT

Suggesting phonetic value of glyph elements, one may expect to observe traces of separate carving both in ligatures and individual signs. Indeed, the photos of the tablets reveal the segmentation of practically all the signs, even anthropomorphic



Figure 4. Examples of sign segmentation and correction.

and zoomorphic ones (Figure 4). Observed segmentation has no relation to division lines that appear during the correction of erroneously written glyphs. The latter certainly would introduce the distortion of sign elements, as has happened with the left hand of glyph 595, line Gr3, which is carved so thinly into its place after the entire sign was written, or with two heads in line Br5, carved again in full size. Sign 604 (Figure 4, Cb2) first had the hand 064 corrected to the ligature 600.064, repeated immediately in separate form. It is worth noting that such correction-related divisions are rare, while the great many of well-proportioned signs on different *rongorongo* artifacts feature traces of clear segmentation, which reflects their initial compound structure. Naturally, the segmentation is less pronounced for tablets of superior craftsmanship, such as B, G, I, P, and R, most probably made by professional carvers. The artistic quality of tablets A, F, K, Q, and S suggests that they were made by less experienced scribes, but these tablets may contain more important information regarding the writing process, because it is the beginner scribe who spells out every word clearly.

Lozenge-shaped heads of anthropomorphic glyphs seem to be carved as a separate element, identifiable with rotated sign 002 (Figure 5, Sa4-Fa4), suggesting that even basic anthropomorphic glyphs could be ligatures of abstract-looking components. If true, the wisdom of the *maori rongorongo*, who camouflaged a phonetic script as a pictographic one deserves admiration. Such a writing system would have served well the purpose of sending a message that was unreadable for the messenger (Ayres and Ayres 1995:23).

Sign 200 duplicates as a hands-joined ligature 200.200 and both hands/feet joined glyph 209 (Figure 5). The latter sign in line Bv6 is replaced by glyph 208 with two bodies but one head in corresponding parallel fragment Bv5. Reduplication is also used to form Rapanui words. It can be either total (*mea* – fish gills, *meamea* – dark red) or partial; the latter usually duplicates the first syllable of adjectives (*tea* – dawn, *tetea* – whitish), disyllabic words, and trisyllabic words with initial vowel ('*o'otu* – burn, '*o'o'otu* – burn very much) (Du Feu 1996: 191). Such similarity between sign and word ele-

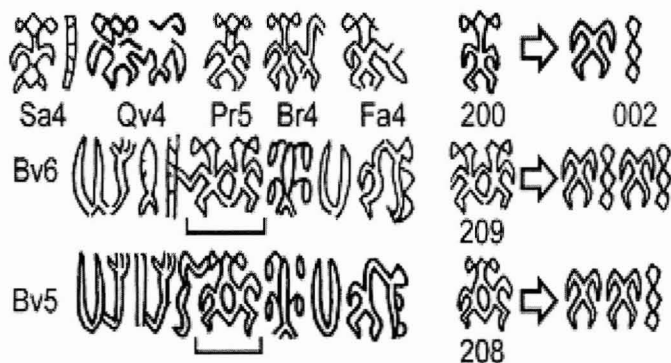


Figure 5. Lozenge head anthropomorphs: calligraphic variants and proposed decomposition into basic elements

ments allows for the assumption that glyphs 208 and 209 could be partial and complete reduplications of sign 200, respectively (Figure 5).

Sign 005 is the most possible allograph of long-haired head signs (glyphs 530-539). The similarity becomes clear considering the half-rotated sign: its right ear substitutes for the neck, while the left one is depicted in the style of lozenge-shaped heads (Figure 6). Possible evidence for this assumption includes the sign 539 in line Aa1 (first occurrence of glyphs 530-539 in this tablet) with the rather uncertain carving of the head, featuring extra lines making it similar to glyph 005. The next group of signs with the same head type in line Aa2 are better carved, but the lower line demarcating hair al-

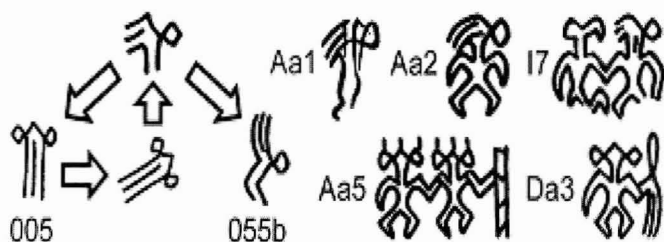


Figure 6. Possible allographs of head form 530-539.

most separates their heads (Figure 6). From here on, the scribe seems to have had enough practice with this head form, as all other signs 530-539 appearing on *Tahua* tablet are normal.

Ligature 600.530, line I7 (Heyerdahl 1965: Figure 193), uses both head forms, as if one were written first and then corrected. It is curious that the Santiago staff, counting about 3000 glyphs in Barthel's notation, almost lacks sign 005; there are only 18 glyphs of this kind, yielding three times fewer occurrences in comparison to other tablets. Normally, any text of sufficient length, written in natural language, must include a

certain number of each element proportional to its average use frequency. Low occurrence of an otherwise common sign is possible when the text uses its alternative calligraphic form. Glyph 055b with its upward-combed hair, occurs 19 times on the staff, and is the most probable allograph for the head 530-539 (Figure 6). In transliteration, glyph 055b, sometimes assigned the code 006, which corresponds to a different sign – a hand with three fingers and a thumb. Possible allographs of



Figure 7. Parallel fragments of the tablets B, G, and S.

glyph 005 may also include a lozenge head with vertical lines (occurring mainly in text A) and the hand 052, adorned with super/subscribed sign 022 (Figure 6).

Numerous groups of the signs 300-459, composing about one tenth of the entire *rongorongo* corpus in Barthel's notation, have a gaping-mouth head shown in profile. As it follows from the parallel fragments illustrated in Figure 7, underlined groups 381.009 and 045.061.009 can be identical, if the presence or absence of body form does not affect the reading of the fragment and if glyph 045 represents an allograph of the gaping mouth head; the latter looks feasible if rotated glyph 045 is concerned. The frequent ligature 073.006, occurring 41 times (including almost 40% of all signs 073) is used in parallel fragments Ca2/Pr9 in place of sign 386 (Figure 8), suggesting allographic parallels between glyph 073 and the gaping mouth head. A similar form is characteristic for the sign 076, most frequently appearing on the Santiago staff (Fischer 1995:306). In several cases this suffixed separator is depicted exactly as a gaping mouth head (Figure 8, I5),

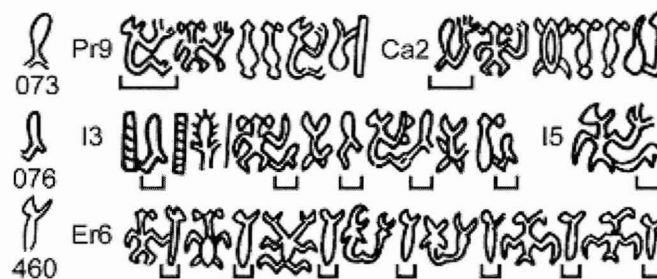


Figure 8. Suggested allographs for gaping mouth head.

especially when fitted into narrow spaces. Another gaping mouth glyph 460, resembling vertically-flipped sign 076, can be also used for text separation purposes (Figure 8, Er6).

Such a stable repetitive pattern must have parallels in the Rapanui language, if the script is phonetic. Taking into account that the tablets may contain chants or songs, it is possible to suggest that sign 076 corresponds to the vocative parti-

Eaha to rau ariki ki te mahua i uta nei?
E ura e poopoo e koiro e nohu
to rau ariki ki te mahua i uta nei
 (Thomson 1889:523, Fedorova 1978:315)

Ka tagi e ere ika iti e
mo nua e ere mo te matua e
 (Campbell 1999:213)

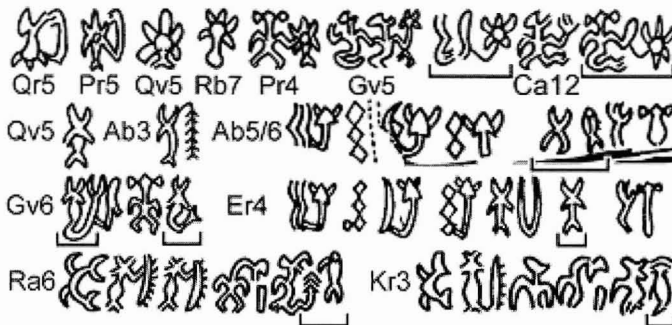


Figure 9. Examples of ligatures with top-down reading.

Although the majority of the glyphs obey a bottom-up reading rule, some exceptions exist. For example, sign 551 (Figure 9, Qr5) reveals evidence that element 460 was carved first, followed by a simplified star 008 and finally by the hand 061. This yields exactly the same element sequence for bottom-up ligature 081.061 in the parallel fragment (Figure 9, Pr5), if sign 073, an allograph of 460, is considered as the tail of a star 081; this is proved by the segmentation observed for other occurrences of sign 081 (Figure 9, Qv5, Pr4). Glyph 073 can be written as an elbow adornment (Figure 9, Gv5) which is also common with the hand 006; the latter correlates well with frequent ligature 073.006. Hands with rounded tops may be another allograph of sign 073. In the example considered (Figure 9, Ca12), the sequence 060-044.008 was rewritten as the ligature 275.008, violating bottom-up reading, because its body (which one would expect to be written after the leg 060) is absent in the first sequence.

Marine creatures 730-739 were also probably carved from the top (Figure 9), judging from their oversized heads with characteristic body division (Qv5); if the latter is absent, the tail can continue bottom on the right extremity of the head (Ab3); sometimes an already carved symbol can have a tail added (Gv6) or both elements may appear separately, when there is no place for the composite sign (Figure 9, Ab5/6, Er4). Elements 069-700 in the sequence, discussed by Pozdnyakov (1996:295) also form glyph 580 with assumed top-down reading.



Figure 10. Suggested compact form of the signs.

The *rongorongo* script seems to use simplified glyph forms, joined to other signs. For example (Figures 10, 17), in the fragment 070-027-141.076 glyph 141 may be a possible reduplication of the first two, if one considers its thorns as a compact form of sign 070, and the body as the rotated glyph 027. Assuming thorn-bearing bar 013 as another allograph of sign 070, one can obtain a good correlation between two parallel versions (Guy 1985:378) of the same fragment (Figure 10, Aa1, Pr5); this result agrees well with the decomposition example suggested by Macri (1996:186). A partial depiction of sign 002a (Figure 10, Pv5) is similar to three protrusions added to some glyphs; this analogy can be illustrated with sign 090f, consisting of the same elements 002 and 022f, as the following glyph 020f (Figure 10, Ra4). Similar protrusions also are attached to the hands (Ra3) and even bottom side (Pv5, glyph 346) of anthropomorphic signs. The compact form of glyph 002 also includes single protrusions of lunar-shaped objects (Da4, Cb12) and two protrusions merged to the long beaks of glyphs 660-684 (Figure 10, Aa4, Pr7). Glyph 440, with similar adornments (Qr5), can be an allograph of the latter head type; the evidence supporting this can be obtained analyzing the calligraphy of the signs 660-684 (e.g., Figure 10, Ab1). Despite interchangeable usage, a head on a long neck (glyphs 460-499) and long-beaked bird-head are possibly spelling variants rather than allographs, as the former is never added with the compact form of the sign 002.



Figure 11. Calligraphy and proposed decomposition of sign 280. Design carved on *moai pa'a-pa'a* head (after Butinov, Rogozina 1958: 312). Suggested allographs.

Analysis of a frequent sign 280 (Figure 11) reveals that its arched upper fins, resembling those of a turtle, are often carved separately (Aa8) and can be straight (Kv2, Ev7, also Br8) or joined to the neck rather than to the body (Qv1, Sa6, Tomenika script (Routledge 1919: Figure 99), suggesting decomposition 070.002 for sign 280. This approach seems feasible for the similar glyphs, including those with an inner oval, inherited from the sign 070a. The proposed decomposition allows for calligraphic discrepancy in parallel fragments Hv8 and Pv9 (Figure 11), yielding the same element sequence 070.002 for sign 126 (a vertically-flipped body of 280a) with added bottom protrusions (possible compact form of sign 002). It is also interesting to note that line Hv8 has an example

of sign 001 written almost over a wood surface defect, while the corresponding line Pv9 uses in this place glyph 106 – a vertical bar with a circle in the middle, which can be probably considered as possible secondary evidence that the tablet P was inscribed from the original tablet H or maybe from its copy.

The anagram adorning the head of *moai pa'a-pa'a* in the collection of MAE, St. Petersburg (Kudryavtsev 1949:186, Butinov and Rogozina 1958:312) also suggests the sequence 070-002, as the double-outlined external glyph was most probably carved before the inner element, which appears less artistically executed fitting into its place. Assumed parallels with *rongorongo* signs suggest that the anagram can be an inscription. Morphologically similar glyphs 148-151 also feature less-detailed inner elements. Analysis of parallel fragments Pr8 and Br9-Br10 (Orliac and Orliac 1995:64-65, photo) allows removal of the allographic discrepancy, if the signs 156 and 101 (Figure 11) are considered to be equivalent ligatures 022.103 = 022.037.



Figure 12. Glyph 003 and feather-adorned elements.

Sign 003 is characterized by a general suffix use (359 of total 440 occurrences), sometimes forming series separating individual glyphs in lines Ab3 / Ab5 / Hr3 / Pr3 / Qr3, Bv4, Cb1, Cb10 / Cb12, Db2, and Sa6 (Figure 12). Parallel texts of the tablets H, P, Q, and A prove that this sign can be omitted without significant influence on the remaining glyphs (Olderogge 1947:237). Some examples show sign 003 as bracketing the glyph or separating the elements, re-written again in a single ligature (Figure 12, Cb5, Da6). Special attention should be paid to the almost complete absence of sign 003 in text I, with only five occurrences in total: line I4, 003.001V-430.076, 090.003-009.076, 451.003.076-254; line I6, 071.003-632, and possibly one more in line I9, transliterated as 060.069-379. Considering that three out of five cases belong to the same line, it seems logical to look for an alternative calligraphic variant. The staff is the only *rongorongo* artifact with vertical lines that act as text delimiters (Fischer 1995:305); possible corroboration is seen in manuscript E (Heyerdahl 1965: Figure 192), using vertical lines to separate textual fragments. It is reasonable to suppose that vertical line 003 had exactly the same function. An analysis of similar fragments of lines Aa1 and Qr6 (Figure 12) suggest that feathers added to the glyph element can be a compact form of the sign 003. Considering possible types of feather-wearing elements, one can assume the allography of signs 059 and 499 with the head characteristic to the glyphs 520-529, judging from different calligraphic variants of the sign (Pr9, Rb2, Fa4)

and parallel fragments, such as Cb10 and Pr3 (Figure 12). Usage similarity provides the evidence that glyphs 048 and 049 are different forms of the same sign. Under these assumptions, it is worth noting that 85% of all feathered elements belong to five basic types, which suggests the presence of a local delimiter at each element. This observation assumes a possible parallel between the addition of the feathers and the glottal stop, delimiting five vowels of Rapanui language (Englert 1948:328).

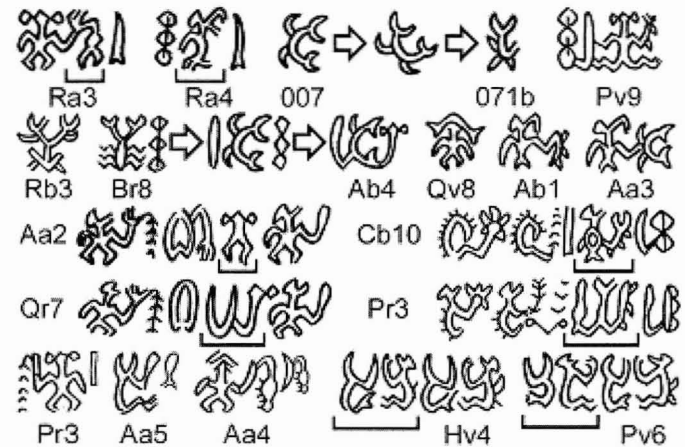


Figure 13. Possible allographs and general observations.

Evidence suggesting the possible allography of signs 058 = 075 with an open-beak bird head is shown in Figure 13 (Ra3, Ra4). *Rei miro* sign 007, rarely appearing on the Santiago staff, probably corresponded to glyph 071b, also usable as a hand (Pv9). The rotated sign 007 can form double heads (Figure 13, Qv8, Rb3), maybe even those of sign 770, where elements 022, 073 or 070 may form its body (e.g., compare Br8, Ab4). Sign 007 seems to have a compact form 071 (Ab1, Aa3), removing discrepancies in parallel fragments Cb10, Pr3 (Figure 13). Passages Aa2 and Qr7, discussed by Kudryavtsev (1949:191), suggest that the feet of the sign 093 (and similar signs 511, 571, 591) can be formed by vertically flipped glyph 027.

Special attention must be paid to the hands assigned with lower digit 5 in Barthel's notation, because they show distinct calligraphy of glyphs 001, 073, 040, even creating characteristic combinations (Figure 13, Pr3, Aa5, Aa4). Mirror reflections of the signs probably served ornamental purposes only (Hv4, Pv6), creating groups resembling the motif *manupiri*, used in Rapa Nui rock art (Lee 1992:70).

PROPOSED GLYPH ELEMENT CLASSIFICATION

Based on the results of paleographic and statistical analysis of *rongorongo* texts, a catalog of 50 possible glyph elements (Horley 2005) with their main allographic variations was constructed (Figure 14). Each is assigned a two-digit number, distinguishable from the three-digit codes of the extended Barthel system. Glyph elements were catalogued, maintaining compatibility with Barthel's nomenclature as much as possible. When the element was absent among signs 001-050, a new code with the same low digit was assigned (i.e., signs 060-064 were re-mapped into 30-34).



Figure 14. Proposed catalog of glyph elements with two-digit code and main allographs denoted with letters.

Suggested allographs are distinguished with a letter, denoting six main forms: alternative, bottom-up, compact, rotated, and with feathers; letters g, h, i, j, k are reserved for other variations. In particular, h marks the hand version of the elements 01, 22, 40, 45. Letter o is suggested to represent ear-like protrusions, so far proving to be ornamental. As in Barthel's transliteration system, juxtaposed and linked signs are designated by a hyphen and a period, respectively. Superscripts, subscripts and overall sign composition can be handled better with common mathematical notations, i.e. caret '^', low line '_' and parenthesis (Figure 15). Illustrated examples of the proposed transliteration system allow us to reveal text similarity, unobservable in Barthel's notation, removing discrepancies in parallel texts Hv7, Pv7, and highlighting new parallel fragments, such as part of the inscription in lines Ca2, Pr9 repeated on Small Santiago tablet, line Gr5.

STATISTICAL ANALYSIS OF GLYPH ELEMENTS

The total number of glyph elements, 50, allows for analogies with the syllables of the Rapanui language. To investigate a

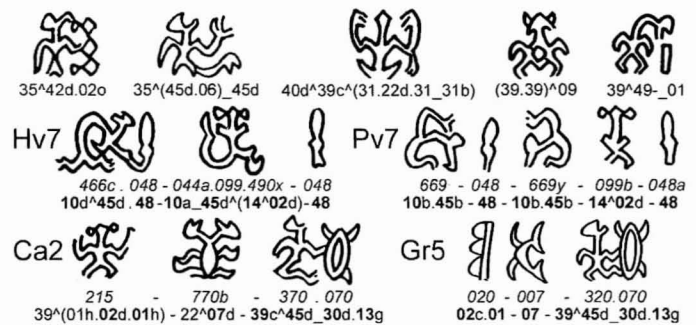


Figure 15. Examples of proposed transliteration showing similarities unobservable in Barthel system (in italics).

possible relation between them, *rongorongo* texts were transliterated from the photos of original tablets A-E, G, H, P-S and the Barthel / Philippi tracings for the Santiago Staff. The texts of the tablets H, P, Q were reconstructed using their parallel fragments. About 5% of the signs (in Barthel's notation) of all the tablets mentioned were discarded: those lacking identification due to wearing, and a fraction of highly repetitive text delimiter glyphs; e.g., only 16 of 32 occurrences of ligature 380.001.003 were considered for lines Gr3-Gr7, avoiding statistical distortion for a limited-sized corpus. Tablet K was discarded as having almost the same text as Gr1-Gr7; tablets F, J, L, M-O, T-Z were not considered, being fragments. The resulting corpus included 17,508 elements, grouped into 7,657 words. The main characteristics of the individual texts are given in Table 1. Element per word (E/W) value is similar for all the tablets. The content-dependent lexicon-word (L/W) ratio features weak deviations from the mean value, 0.46.

Table 1. Statistical characteristics of *rongorongo* texts.

Text	Elements	Words	Lexicon	E/W	L/W
A	2897	1289	515	2.25	0.40
B	2155	935	423	2.31	0.45
C	1299	594	261	2.19	0.44
D	442	188	114	2.35	0.61
E	972	441	221	2.20	0.50
G	1033	432	233	2.39	0.54
HPQ	3072	1324	571	2.32	0.43
I	3811	1613	544	2.36	0.34
R	761	353	160	2.16	0.45
S	1066	488	221	2.18	0.45

Word distribution for the number of composing elements is plotted in Figure 16.a for individual texts. All curves feature similar behavior; the most significant deviations observed for Tablet D are expected since its text is rather short. Increased word length for tablets G and I (clearly distinguishable for four-element words) can be explained by the presence of the suffix glyph 076. Figure 16.b presents word distribution regarding numbers of composing elements for the *rongorongo* corpus and syllabic representation of folklore texts (hollow sym-

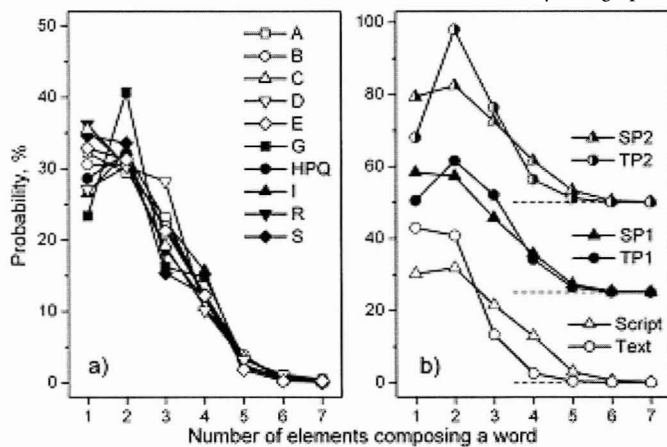


Figure 16. Word length distribution for the tablets: a) total script and text corpora b) progressively offset vertically in 25% steps to improve the presentation.

bols), revealing a rather poor qualitative agreement between the curves. The suggestion that stable groups of juxtaposed elements meaning one word but counted as two, seems feasible for the case of mono- and di-syllabic words, but it fails to explain significant difference observed for three- and four-element words.

A possible solution to the problem can be found by analyzing incorrect word divisions (Fedorova 1978:10) in the Rapanui manuscripts (Heyerdahl 1965: Figures 96-192). Curiously, several fragments feature a specific writing style, giving the impression of a highlighted syllabic nature:

*he no ho a te KaPu mea Ko Pao atoPa tahi te Kio
i mu ri ia paoa A hei, hetai na apaoaAhei o u re a reKa,*
(Heyerdahl 1965: Figure 139)

The same passage, with correct word divisions:

*He noho a te Kapu mea, ko paoa topa tahi te kio i muri
ia paoa a hei. He taina a paoa a hei o Ure a Reka.*
(Fedorova 1978:188)

The most important peculiarity of the Rapanui manuscripts is the joint writing of the words preceding or following *i*, *te*, *he*, *ko*, etc., in the majority of cases:

*Ku ma tero ai, tepapa Ku, itoga ri Ki, Kuoho roai,
teta gata, Kito ga ri Ki.* (Heyerdahl 1965: Figure 164)

*hetuu Kite mana vai te Kuhane ohau maKa. henape ite
igoa Kote mana vai a hau maKa o hiva. l*
(Heyerdahl 1965: Figure 192)

A similar way of writing was also used by Englert:

He-ki A'Te Kahumea: "Ku-mao-a". (Englert 1948:384)

Considering the possible joining of article *te* to either the previous or the following word, both possible cases were investigated, pre-processing folklore texts in the following way: the first method (TP1) considered joining the particles *he*, *ku*,

te to the next word; the second one (TP2) joined *ku* and *he* to the next, but *te* to the previous word. Two pre-processing methods were also applied to *rongorongo* corpus: first method (SP1) consisted in omission of suffix elements 45c(076), 03 (suggesting excessive text delimiters), and accounting feathered elements as unitary symbols. The second method (SP2) omitted elements 45c, but kept signs 03, suggesting its suffix position indicative for possible relation with the article *te*, treated according TP2. For the same reason, feathered glyphs were expanded into two symbols (i.e. 20f = 20.03). Resulted numerical characteristics of text and script corpora are given in the Table 2.

Table 2. Characteristics of text and script corpora

Corpus	Elements	Words	E/W	Lexicon
Text	79658	45144	1.765	1679
TP1	79658	35403	2.250	2947
TP2	79658	35408	2.250	2977
Script	17508	7657	2.287	2010
SP1	16373	7584	2.159	1788
SP2	17429	7595	2.295	1958

As one can see from the table, both pre-processing methods yield almost equal results regarding word number and lexicon size; but comparing the curves presented in Figure 16. b, it becomes obvious that TP1 and SP1 correlate much better for all numbers of elements observed, while TP2 distorts the statistics, overloading it with frequent di-syllabics *kite*, *ite*, *ote*, etc.

Probability-rank curves, presented in Figure 17 for pre-processed and processed corpora reflect the significant qualitative agreement obtained upon processing. Despite the better visual impression from the low-rank coincidence between TP2 and SP2, their entropy values show greater difference than those between TP1 and SP1. Probability-rank curves built for glyph elements and Rapanui syllables (Figure 18) show good correlation, again more pronounced for the SP1 *rongorongo* corpus, judging from calculated entropy values.

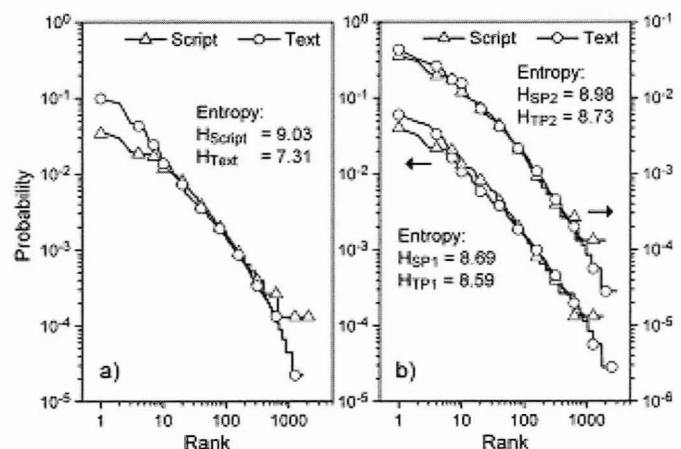


Figure 17. Word probability-rank plots and entropy *H* for the script and texts prior to (a) and after processing (b).

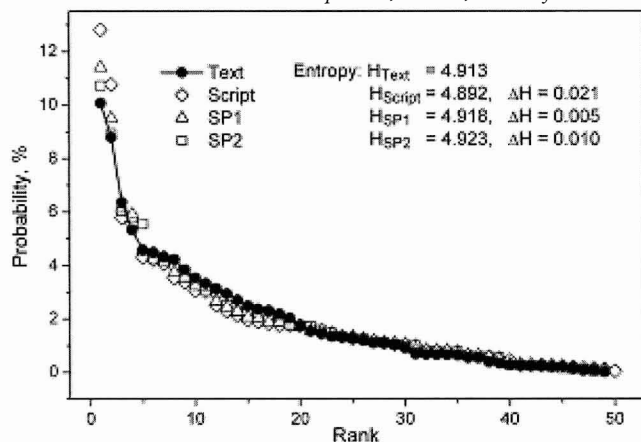


Figure 18. Probability-rank curves for glyph elements and syllables forming Rapanui folklore texts.

Therefore, statistical results supply evidence to suggest the phonetic character of *rongorongo* writing, with each glyph element representing a syllable. For both pre-processing methods, it is possible to confirm that syllable occurrence statistics corroborate the assumption that elements 02, 22, 45, 48 49 can represent vowels, suggesting that element 02 (with occurrence probability $P_{SP1}(02) = 11.4\%$ and $P_{SP2}(02) = 10.7\%$, respectively) correspond to the syllable *a* ($P(a) = 10.1\%$). For the SP1 corpus, frequent prefix element 39 correlates well with the particle *te*. As the absence of an article does not introduce significant changes to the text, one automatically obtains a feasible explanation to the body omissions observable for anthropomorphic signs. Under these assumptions, glyph 200 obtains possible reading *tea*, sign 209 – *teatea*, and other multi-element forms may yield *teana*, *teahu*, *teariki* (or *tea riki*) and so on.

Using statistical data, it is possible to estimate the length of the syllabic text corresponding to *rongorongo* inscriptions. In particular, the SP1 corpus will be about 35,042 characters long, counting 1.677 letters per average syllable plus space to separate words, filling some seven single-spaced A4 pages with two-centimeter margins, typed in 10 pt Courier New font. For comparison, manuscript E would occupy thirteen pages in the same format.

POSSIBLE PARALLELS IN RAPANUI CULTURE

Analyzing the list of common Rapanui names (Fedorova 1982:59-60), one can find that the majority consist of two or three syllables, making a single compound *rongorongo* sign suitable to render a name or a short toponym. Similarities between numerous petroglyphs and *rongorongo* glyphs were already widely discussed (Lee 1992:126-128; Macri 1996:184; McLaughlin 2004:92-93), but, to our opinion, there can be more designs showing positive correlation, including petroglyphs adorning sacred red scoria formations, characteristic of the late historical period (Lee 1992:122). For example, three *rongorongo* signs appear on the topknot once belonging to a statue of *Ahu Akahanga* (Figure 19a). The nearby *pukao* is adorned with a bird with a distinct separately-carved head, similar to that of the sign 400 (Figure 19b). A topknot blank at *Puna Pau* contains shapes identifiable with glyph elements, as

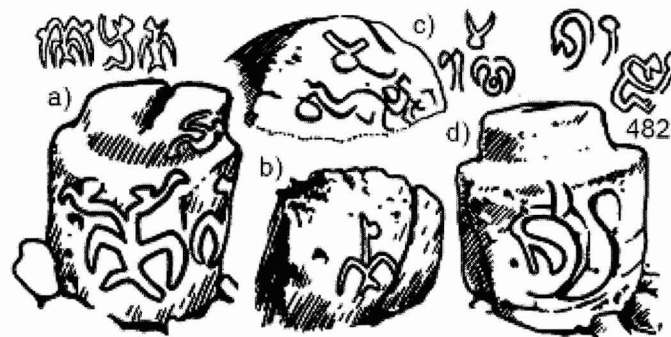


Figure 19. Red scoria designs which may have relation to *rongorongo* inscriptions (from photos by the author): a) and b) *Ahu Akahanga* topknots, c) *pukao* blank from *Puna Pau* quarry and d) *Ahu Hanga Tee* (*Vaihu*) topknot (compare its elements with those forming glyph 482).

does one *pukao* at *Vaihu* (Figures 19c, 19d).

One may also mention the head of a fabulous creature skillfully carved over a boulder at *Hau Koka* (Figure 20a) with joined nose and mouth, which features unusual ears with pointed earlobes and rounded ear rim, connecting to the nose via arched eyebrows. Details mentioned suggest a similarity to a *rongorongo* glyph with two bird heads, as those of the signs 680-684. It is tempting to suggest that the glyph was carved first, transformed into a bearded face by further adornment. A sea creature with open mouth, belonging to the same site (Figure 20a, lower left), has the characteristic elements of glyph 733, especially in the calligraphy of tablet *Keiti* (Figure 8, Er6).

Element 38, appearing in the famous *Ana o Keke* petroglyphs, gives an impression of deliberate placing under the cupule, and probably intended to represent the head (Figure 20b). Combining the following elements, a *rongorongo* line can be formed (Figure 20b). More *rongorongo* parallels may exist in designs that adorn the heads of wooden figures; note the separately carved bird body, corresponding to element 35 (Figure 20c), and a composition that includes the moon and two birds is similar to that of line Qr4 (Figure 20d).

The most important conclusion can be obtained by ana-

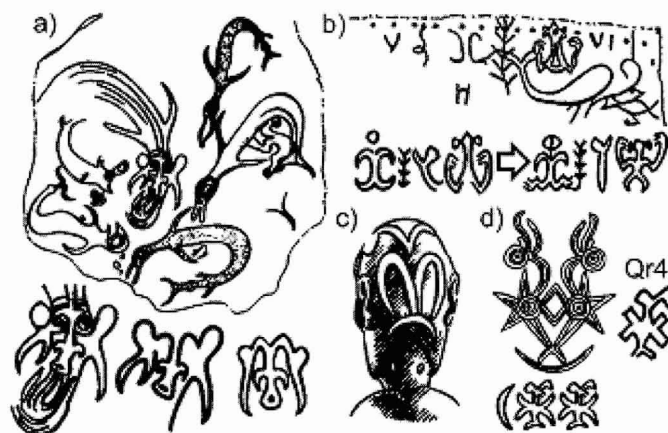


Figure 20. Possible *rongorongo* motifs: a) *Hau Koka* (Lee, 1992:164) and b) *Ana o Keke* petroglyphs (Lee, 1992:47) with possible elements and signs. Adornments carved on of wooden figures: c) kneeling man, Boston (after Heyerdahl 1975: pl. 79), d) *moai kava-kava*, MAE, St. Petersburg (after Butinov and Rogozina 1958).

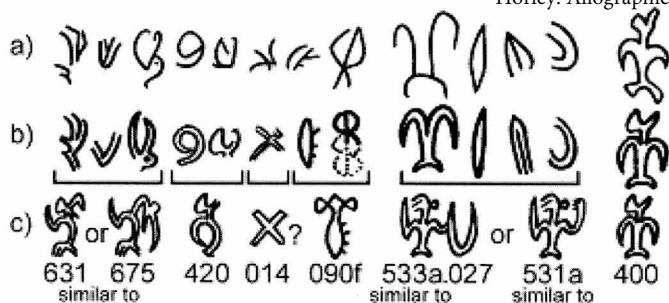


Figure 21. Signatures of the islanders on Spanish treaty:
a) from (Heyerdahl, 1965: Fig. 81); b) proposed set of elements and
c) suggested *rongorongo* inscription.

lyzing the signatures of islanders on the Spanish treaty (Heyerdahl 1965:345, Figure 81). Rapa Nui chiefs drew a single *rongorongo* glyph 400, which appears rather clumsy, using new unknown paper-and-pen writing; but perhaps because of this, the rest of the inscription consists of simple signs, identifiable with glyph elements and yielding a line that can be successfully converted into known *rongorongo* signs or very similar glyphs (Figure 21). Use of fragments rather than compound glyphs can be observed also in the Tomenika script (Routledge 1919:250, Figure 99), representing the *tau*, or inferior type of *rongorongo*. The latter suggests that both writing systems could have used the same elements with possible syllabic value, written in a row in fluent *tau* or joined into compound glyphs in elaborate *rongorongo*.

Taking into account the glyph elements appearing in the signatures of islanders on the Spanish treaty and also in seen on red scoria petroglyphs, as well as the fact that one of the largest inscribed tablets, *Tahua*, was made from a European oar of the 18th or first half of 19th century (Métraux 1940:393), it seems reasonable to assume that *rongorongo* script was already fully developed before the contact with Europeans and was in use when the expedition of González visited Easter Island in 1770.

CONCLUSIONS

Results of the paleographic and statistical investigation of *rongorongo* texts, presented in this paper, suggest the presence of a large phonetic element in the script. The newly proposed transliteration method, based on glyph elements, allows us to reveal new similar fragments and to remove allographic discrepancies in parallel texts. Comparative statistical analysis of Rapanui folklore, including word and syllable occurrence frequency, word length statistics, and syllable and lexicon entropy proved a good correlation between elements of *rongorongo* glyphs and syllables of the Rapanui language, thus allowing the suggestion of possible functions and probable readings of several elements. Parallels between *rongorongo*, petroglyphs, and wood carving designs are proposed. Common glyph elements constituting the signatures of the islanders on the Spanish treaty and appearing in late red scoria petroglyphs, support the theory that the *rongorongo* script was developed before European contact and was still used on the island in the late 18th century.

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